Laboratory Centralized Demand Controlled Ventilation System Increases Energy Efficiency in Pilot Study

Laboratory ventilation rate guidelines are usually applied as constants, with the chosen ventilation rate rarely dynamically controlled or otherwise tailored to the occupancy or conditions of the lab. This neither optimizes energy efficiency nor safety. Some guidelines simply recommend a range of 4 to 12 air changes per hour. The result can be excessive ventilation for the lab resulting in unnecessary energy expenditures.

1 Introduction

Laboratory ventilation rates can be reduced by using a demand-controlled ventilation (DCV) system that incorporates sensors to monitor real-time lab pollutants. A centralized demand-controlled ventilation (CDCV) is a technological approach that uses a centralized suite of pollutant sensors to provide DCV. A CDCV system is intended to minimize DCV complexity and cost of installing multiple, dedicated pollutant sensors in every lab in the facility. With CDCV, a sample of each lab's exhaust air is retrieved from each lab, in turn, and brought to a centralized sensor-device for analyses. The central device includes multiple sensors for the pollutants expected to be encountered in the facility. If a pollutant detected in a lab exceeds a pre-determined threshold, then the lab ventilation rate is increased to a much higher rate until the spill is cleared from the lab. Spill clearing time is monitored by the CDCV and reported to the building management system (BMS).

2 Benefits for laboratories

Laboratory owners can benefit from the significant reduction in energy use resulting from reduced ventilation rates. CDCV monitoring equipment can detect hazards and alert staff. In addition to monitoring for spills and other minor excursions, CDCV can also identify malfunctioning fume hoods or poor lab practice that could otherwise go undetected such as chemicals left out of fume hoods.

In new laboratory designs, a CDCV system provides an opportunity to right-size the heating, ventilation, and air-conditioning (HVAC) system that could reduce its size and energy use. A relatively smaller space-conditioning system can help offset the cost of a CDCV system.

3 Retrofit Opportunity for CDCV

In existing lab facilities, installing a CDCV system requires multiple levels of interfacing and coordination because the impacts on safety, research procedures, and HVAC operations. For example, the HVAC and BMS must have the capability to vary air flow rates. Therefore, it is important to conduct meetings with users, researchers, environment, health, and safety (EH&S) representatives, facility personnel, and other stakeholders. Once these meetings have been completed, it will be necessary to coordinate a series of baseline tests of facility operations and simulated spills. After installation, the CDCV system must be thoroughly commissioned to ensure the expected response by the HVAC system is achieved.

Install and Commission CDCV

A thoroughly commissioned CDCV system will ensure optimization and persistence of energy savings. One of the benefits of a well-operating CDCV system is the ability to easily perform on-going, continuous commissioning (CCx) of the laboratory. CCx can help identify additional energy-savings opportunities such as simultaneous heating and cooling, poor sensor calibration and drift, sub-optimal control strategies, and premature component failures.

3.1 Lessons Learned at the University of California, Irvine (UCI)

A pilot study of a CDCV system at UCI resulted in perceptible increases in the lab's ventilation rate during simulated spills and other test-runs. In this case, there was a clear cause-and-effect response, which validates these claims made by the manufacturer. Although the CDCV system can improve lab safety, it is primarily intended to reduce lab energy use without compromising lab safety and, as such, the CDCV system alone should not be considered a "safety" system.

Pollutant Accumulation and Airflow

Regarding pollutant accumulation and lab airflow, the ANSI/AIHA Z9.5-2010 Laboratory Ventilation Standard in Section 2.1.3 Dilution Ventilation, under *Requirements of the Standard* states, "Dilution ventilation shall be provided to control the buildup of fugitive emissions and odors in the laboratory." This section of the standard continues, under *Clarification and Explanation of the Requirements*, to also say that, "Control of hazardous chemicals by dilution alone, in the absence of adequate laboratory fume hoods, is seldom effective in protecting laboratory users. It is almost always preferable to capture contaminants at the source, than attempt to displace or dilute them by room ventilation. Nevertheless, dilution or displacement may remove contaminants not captured by a specifically applied device. The quantity of dilution (or displacement) ventilation required is a subject of controversy."

Notably, the issue of an appropriate ventilation quantity, or rate in laboratories continues to be a source of much discussion and debate. A common assumption during lab design is that relatively higher rates of ventilation provide safer working conditions in the event of a hazardous liquid spill outside of a fume hood. This design approach presupposes that "the solution to pollution is dilution", i.e., increased airflow will dilute pollutant accumulation. From ANSI/AIHA Z9.5-2010 Section 5.3.1 Supply Air Volume, under *Clarification and Explanation of the Requirements*, states, "Numerous studies make it clear that the air flow rate is just one factor affecting contaminant levels in the room. Frequently, other factors have been shown to make a bigger difference than some changes in the air flow rate." However, the rate of accumulation is, in part, determined by the rate of pollutant generation from the spill. As a result, increased airflow will increase this generation rate as well as help clear the evaporated vapors over time.

The spill tests at UCI verified that when high airflow is present in a lab, the evaporation rate of a hazardous liquid spill is greater than with a lower airflow. Both Charts 1 and 2 (below), show the differences between measured pollutant concentrations in each test run at the onset of CDCV operation (at 5-min. and 17-min. interval) and shortly thereafter. These changes in concentrations can be attributed to the differences in evaporation rates and the lab's mixing factor. It is also important to note the pollutant concentrations between the constant baseline airflow rate and the varying CDCV airflow rate.

Chart 1: Spill Plot – 5 minute polling interval

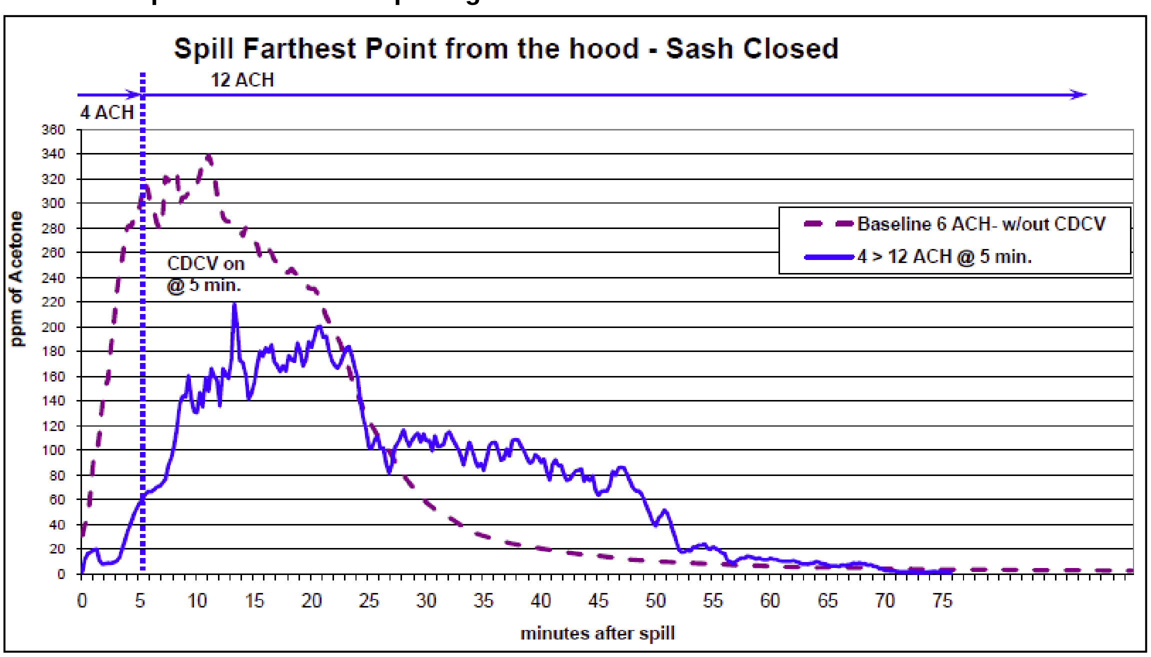
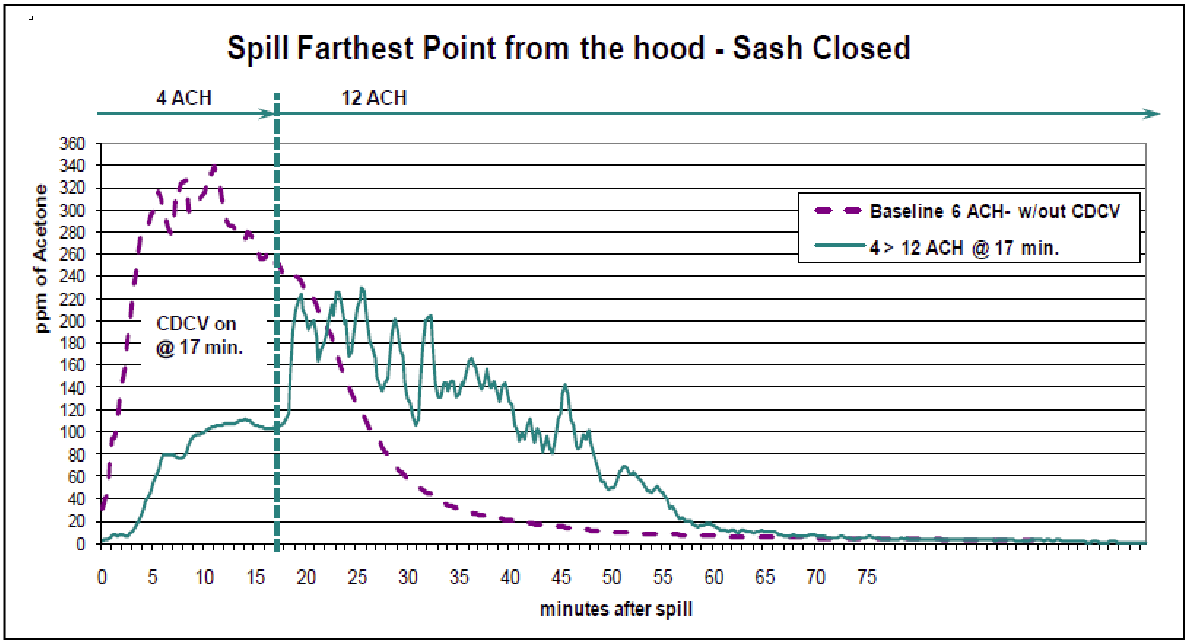


Chart 2: Spill Plot – 17-minute polling interval



Polling Interval

In a centralized sensing system, one suite of sensors is doing the work of many de-centralized sensors. This creates an inherent, built-in polling interval of a fixed duration for each lab on the centralized system. Initially at UCI, this polling interval was 23 minutes meaning that air in a particular lab was being checked for pollutants once every 23 minutes. This length of time was a concern to the UCI EH&S staff. When brought to the attention of the manufacturer, they were able to reduce the interval to a range of 14-17 minutes which approximates the manufacturer's recommendation of 15 minutes. Chart 1 depicts results from an arranged polling interval of 5-minutes. In this test case, the spill was initiated at four minutes prior to the CDCV polling the lab with a one-minute response within the CDCV system. Chart 2 shows the results from a spill initiated just after the usual 17-minute polling interval. Note that in each case, a spill's initial pollutant accumulation was influenced by how quickly the spill was detected. As recommended by the CDCV manufacturer, each laboratory's EH&S and fire-safety personnel and the "authority having jurisdiction" should be aware of this interval, perform a thorough risk assessment, and develop appropriate responses to any hazard notification provided by a CDCV system.

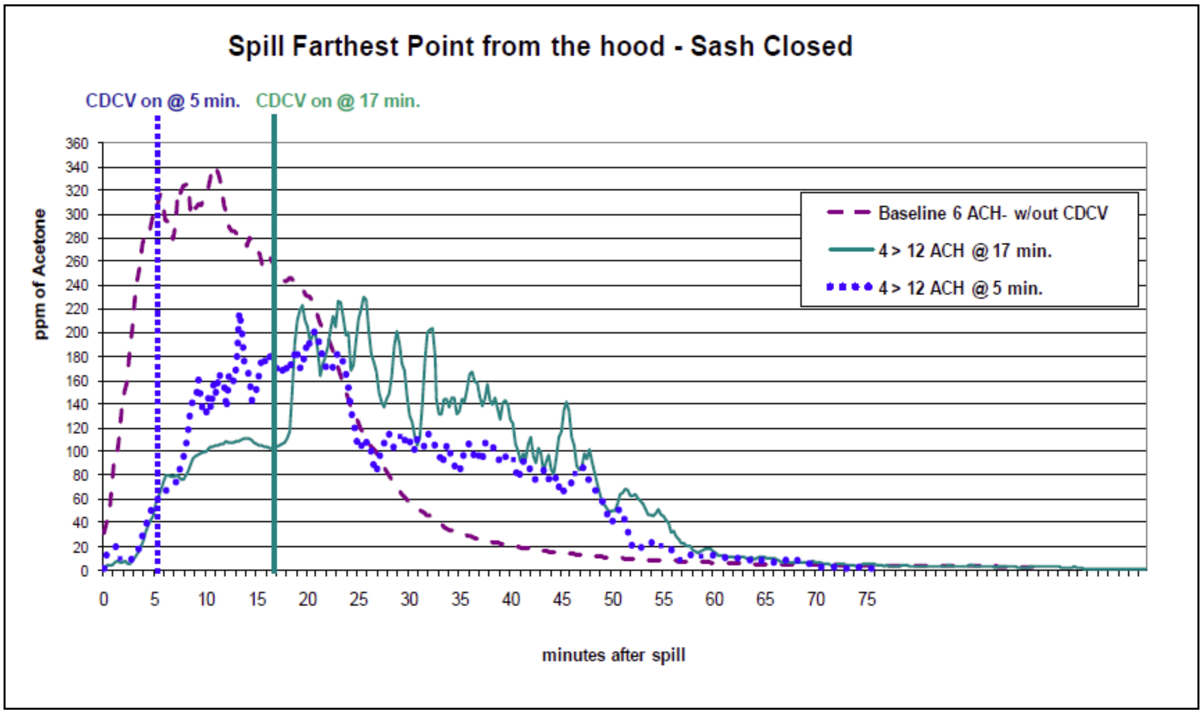
Clearing Time

In each chart, the baseline spill test results show a peak concentration of the hazardous material of 339 ppm of acetone at approximately 12 minutes after the spill was initiated. Due to the relatively higher airflow provided to the lab operating in baseline conditions, the spill concentration dropped to below 50 ppm in approximately 30 minutes. According to a senior industrial hygienist at UCI, the guideline for re-entry by a worker/user into a lab is 10% of the CAL/OSHA Permissible Exposure Limit (PEL) value. For acetone, the CAL/OSHA PEL is 500 ppm. Therefore at a concentration level 50 ppm, a UCI worker/user could reenter the lab. In each chart, the clearing time to a negligible level of 4 ppm occurred at approximately 73 minutes after the spill was initiated.

With the CDCV system in operation, Chart 1 presents the results from the spill test with an arranged 5-minute polling interval showing a peak concentration 219 ppm. In Chart 2, the spill test with 17-minute polling interval resulted in a peak concentration 227 ppm. In both cases, the concentration remained above the 50 ppm PEL threshold for approximately 50 minutes, thus barring a worker/user from entering the lab space for a longer period of time than the baseline situation per the UCI reentry guideline.

In Chart 3, it is important to note that with the CDCV system polling interval of 5-minutes and 17-minutes, the total clearing time occurred at 70 and 76 minutes, respectively. Thus when compared to the baseline clearing time of 73 minutes, there was no appreciable difference in overall clearing time between the 5 or 17 minute polling time compared to the baseline test run at this pilot CDCV system installation.

Chart 3: Clearing times for each spill



Sensor Saturation and Calibration

In the event of a large spill in a lab, it is possible to “saturate” the monitoring sensor. Depending on the manufacturer of the CDCV system, this sensor may need a few minutes time to be purged with unpolluted air to return to a normal state. With a centralized set of sensors, the following scenario could occur: If lab “A” has a spill that saturates the CDCV system, then the system will consider the next lab, “B”, to have a spill and increase its ventilation rate as well. Considering a host of variables, this situation could persist with possible unintended consequences. After a saturation event and depending on the manufacturer of the CDCV system, it may be advisable to have the centralized sensors checked for calibration. According to the CDCV system manufacturer, a normal calibration interval is considered to be six months.

At the time of the pilot installation at UCI, certain compounds, such as chlorinated solvents and formaldehyde, and acids were not sensed by the CDCV system. Since this pilot study, the manufacturer has added a broad-spectrum sensor with possible additional sensors in the future.

3.2 Energy Savings

The CDCV system installation provided tangible energy savings for UCI. Average daily airflow was reduced by over 30 percent, which resulted in a reduction of fan energy use of nearly 40 percent. The staff at UCI calculated the expected annualized savings for the pilot installation that included energy reductions from fans, chillers, and boilers (for pre-heating and re-heating of lab airflow). These data are provided in Table 1, below.

The installed cost of the pilot CDCV system was estimated at $125,000, which included the cost of 5 years of recalibration, sensor replacement, and other purchased annual services. This results in a simple payback of 5.8 years. The installation at UCI was extensively supported by the manufacturer of the CDCV system, thus influencing this cost. Moreover, the UCI facilities staff provided a thorough retro-commissioning of the labs prior to installing the CDCV system. This considerable effort by UCI provided substantive energy reductions that were in addition to the savings noted in Table 1. These energy savings will be presented in another technical bulletin. It is highly recommended in order to optimize a sophisticated CDCV system's energy savings, the basic HVAC system's operation must be examined and fixed as a first step.

Table 1: Energy Savings from CDCV

Sample Data			Annualized			
	Average CFM	**kW Load**	**Fan Energy kWh**	**Chiller Energy kWh**	**Preheat MMBtu**	**Reheat MMBtu**
Base	31,454	24.3	213,084	202,900	330	2,957
CDCV	21,739	14.9	130,716	140,216	228	2,043
Savings	9,716	9.4	**82,368**	**62,684**	**103**	**914**
Reduction	**31%**	**39%**	**$ 6,178**	**$ 4,701**	**$ 1,080**	**$ 9,634**
					Total Annualized Savings	**$ 21,593**

1. Used Lawrence Berkeley Fume hood cost calculator to estimate heat load and chiller energy based on UCI-specific central plant efficiencies.
2. Chiller energy use was 0.75 kW/ton and heating plant efficiency was 74%.
3. Climate data was an average of El Toro and Long Beach data.
4. Electrical Cost = $0.075 per kWh; Heating cost = $7.80 per MMBtu/plant eff.

3.3 Next Steps

Since the CDCV system pilot study successfully resulted in energy savings, UCI plans to conduct additional evaluations of CDCV. These evaluations will compare a CDCV system to a zone-occupancy controlled ventilation system by demonstrating their respective impacts on energy savings and safety issues. The CDCV system can support a planned monitoring-based commissioning (MBCx) effort at UCI to identify other energy savings opportunities. It is anticipated that the CDCV system will aid diagnosis of possible excess cooling and reheating due to undesirable interactions between multiple temperature control zones within most of the lab spaces.

4 Acknowledgements

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